SOLVING HOOD CANAL'S LOW OXYGEN PROBLEM, THE ONSITE SYSTEM FACTOR

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ABSTRACT

The Hood Canal, a portion of the Puget Sound estuary, is exhibiting worsening hypoxic conditions and concomitant adverse impacts on the marine biota. A preliminary assessment concluded that nutrient inputs are causing eutrophication and effluent from onsite sewage systems is the most significant anthropogenic contributor to this process. The Hood Canal Dissolved Oxygen Program, an informal partnership of 28 public and private entities, has mounted scientific studies and remedial efforts aimed at restoring the marine water quality. This paper describes the efforts that have been initiated to better manage human sewage in the watershed and the challenges to be faced.
Keywords: Sewage, nitrogen, Puget Sound, marine, onsite

INTRODUCTION

Puget Sound's Hood Canal is a hook-shaped, 60-mile long, glacially carved fjord extending south from Puget Sound's Admiralty Inlet. It varies in width from one-half to four miles and in depth from shallow tide flats to more that 600 feet. At its northerly, inlet end, a sill, or shallow bottom area, transects the Canal at a depth of about 150 feet. Hood Canal receives fresh water drainage from five major rivers whose watersheds cover the eastern slopes of the Olympic Mountains and the western slopes of the Kitsap Peninsula. Several small streams drain directly to the southern hook from a narrow watershed that parallels its most southerly shoreline. Urban development is limited to the unincorporated communities of Belfair at the head of the Canal and Hoodsport on its western shore. Shoreline development of varying density is primarily residential in use. The largest concentrations of homes on small, narrow parcels occur along the northerly and southerly shorelines east of the Great Bend and near the head of the Canal. The current residential population in the watershed is estimated to be near 54,000. However, recreational activities during summer months

temporarily increase the shoreline residential population by an estimated several thousand persons. With the exception of a small number of NPDES-permitted discharges to marine waters or tributaries, all sewage is processed using onsite or clustered treatment systems with in-soil effluent dissipation.

The deep marine waters of Hood Canal have a long history of low dissolved oxygen concentrations during the late summer. Monitoring data documents worsening conditions as measured by increasing persistence over an enlarging area, the movement of mobile marine animals from their normal habitats, and periodic die-offs of fish and other marine animals. Through the Hood Canal Dissolved Oxygen Program (HCDOP), researchers, regulators, federal, state and tribal officials, and concerned citizens are deeply engaged in activities aimed at identifying the causes for declining water quality and remedies that will restore it.

The composition and character of the biota found in a marine water body is largely controlled by the chemical composition of the suspended and dissolved matter in the water column. Of the elements present, oxygen is most critical for the support of the species that are of recreational and economic interest. Low concentrations of dissolved oxygen can have severe adverse effects on these organisms reducing species diversity and causing broad ecosystem change. When the concentration of dissolved oxygen is less than five mg/l some species begin to exhibit biological stress (NOAA, 1998; Bricker *et al.*, 1999). Hypoxia, the low oxygen condition that is deleterious to many organisms, occurs at concentrations less than three mg/l.

The concentration of dissolved oxygen present in Hood Canal's marine waters has been measured since the 1950s, and regularly since the early 1990s, by the Washington Department of Ecology through its Marine Waters Monitoring Program and the University of Washington. Assessment of that data provides information on spatial and temporal changes, as well as a basic understanding of the complexity of the natural and anthropogenic (human caused) factors that impact marine water quality. Developing a better understanding of the impact of those factors on Hood Canal waters is one objective of the HCDOP.

Dissolved oxygen concentrations in Hood Canal's deep waters exhibit seasonal variations. Typically, concentrations are highest in spring, drop to minimum levels by late summer, then begin to rise throughout the fall and winter. Measurements taken over the past few years indicate that the spring highs are at lower concentrations, seasonal recovery is less, and the geographic extent of this condition is expanding from the head of the Canal northward (Newton *et al*., 2002). In fact, at some sampling stations the concentration of dissolved oxygen rarely exceeds the five mg/l "biological stress" level. Fish kills occurred in the spring and fall of 2002 and 2003 causing the Washington Department of Fish and Wildlife to close the Canal to most recreational fishing.

The marine waters of Hood Canal are a highly complex ecosystem that is sensitive to many interrelated impacts, both natural and anthropogenic. Their temporal and spatial variability makes assessing the relative importance of each impact problematic. The

Hood Canal Dissolved Oxygen Program Integrated Assessment and Modeling study (HCDOP-IAM) was established in early 2004 with the objective of conducting scientific studies to quantify the various impacts and develop a model that will facilitate evaluation of proposed corrective actions (Puget Sound Action Team, 2005). An underlying hypothesis is that nitrogen inputs stimulate overly abundant phytoplankton growth followed by their die-off and decomposition that consumes available oxygen.

A parallel effort, the HCDOP Corrective Action and Education group focuses on projects that inform watershed residents about worthwhile remedial actions and demonstrate their application. Jointly, these two efforts involve a partnership of 30 public and private entities focused on restoration of Hood Canal's water quality. The initial work of the Corrective Action and Education group resulted in publication of the **Hood Canal Low Dissolved Oxygen Preliminary Assessment and Corrective Action Plan** (PACA) (Fagergren *et al.*, 2004) by the Puget Sound Action Team and the Hood Canal Coordinating Council. This document examined the human activities that potentially supply nutrients to the marine waters and sought to quantify and rank their importance in order to prioritize early remedial efforts. Of the six major categories identified, human sewage ranked highest.

ASSESSING THE IMPACT OF ONSITE SEWAGE SYSTEMS

The use of onsite sewage systems and their impact on the concentration of dissolved oxygen in the marine waters of Hood Canal must be evaluated as one of many interrelated natural and anthropogenic drivers operating in a limited open system. That system can be characterized as a watershed with an atypical water cycle, i.e., one in which water (liquid) flow is multi-directional. Thus, the chemical constituent balance and the biomass makeup are significantly affected by variation in downstream conditions that are not factors in the assessment of a typical watershed. These include principally, sea surface temperatures and winds favorable to upwelling, either or both of which can impact the natural thermal and density stratification of the estuarine waters, as well as the concentration of nutrients in the euphotic zone, that portion of the water column in which there is enough light for photosynthesis. Also, to be considered in this context is the recurring addition of nutrients resulting from the return of anadromous salmon and disposal of harvested carcasses in the marine water.

Natural and anthropogenic processes within the watershed also influence water quality. Urbanization and its associated human activities, agricultural uses, and forest practices all contribute to increased nutrient input to the marine waters. Monitoring of Hood Canal's water quality and nutrient-addition bioassay studies (Newton *et al*, 1994) suggest that the Canal is sensitive to these nutrient additions, particularly nitrogen. Such additions, it is hypothesized can promote rapid photosynthesis by phytoplankton followed by their eutrophic decomposition.

Household sewage disposal systems are known sources of nitrogenous wastes. PACA participants were challenged to establish an estimate of the contribution these systems make to Hood Canal's low dissolved oxygen condition.

Studies of nitrogen in raw household sewage from individual homes indicate there is significant variation in concentration depending upon household conditions. Concentrations ranging from 25 to 100 mg/l (EPA, 1980; Horsley & Witten, Inc., 2000; EPA, 2002) have been reported. For purposes of the preliminary assessment, PACA participants employed an arbitrarily narrower range, 50 –70 mg/l, as likely to be more representative of the conditions in the Hood Canal watershed. To develop an estimate of the quantity of nitrogen in sewage discharges, additional assumptions were made:

- Once in the groundwater, residual nitrate and nitrite is unreactive, thus ultimately reaching the marine waters.
- The preponderance of systems operating in the watershed are comprised of a septic tank and drain field whose combined nitrogen reduction efficiency ranges from 30 to 70 percent.
- Typical daily water consumption is 60 gallons per capita.
- Per capita production of waste nitrogen is 6 to 12 grams.

Using the estimated year-round residential population estimate of 54,400, flow-based and per capita total annual nitrogen loading ranges were computed to be, respectively, 74 – 241 tons and 39 – 182 tons (PACA, 2004).

A number of uncertainty factors were acknowledged. These included:

- The unknown number of improperly functioning (failing) onsite systems and their relatively larger nitrogen outputs.
- The potentially greater nitrogen contribution from densely concentrated homes along the shoreline.
- The uptake and assimilation of nitrogen generated at a distance from the marine shoreline.
- The summer season population influx.

The lowest estimated value for nitrogen from onsite sewage systems exceeded the estimated input from any other of the six categories of anthropogenic sources by more than a factor of 1.5. Based on this assessment, the PACA participants who served as the human sewage work group concluded that sewage effluent from onsite systems in the Hood Canal watershed is the significant anthropogenic source of nitrogen.

ONSITE SEWAGE CORRECTIVE ACTIONS

The PACA contains several recommendations for action intended to reduce nitrogen inputs from human sewage. These can be summarized broadly as:

- Geographic assessment of facility needs and construction of clustered and community treatment systems with emphasis on land application of treated effluent at sites distant from the marine shoreline.

- Application of new approaches to management of individual onsite sewage systems, including inventories of existing systems, demonstration and assessment of new treatment technologies, and education to encourage broader use and maintenance of nitrogen reducing system components.

Following publication of the PACA, the Puget Sound Action Team solicited contract proposals that would implement its recommendations. More than 30 responses resulted in issuance of 14 contracts. Ten of those support efforts to improve sewage management.

- The Washington State Department of Health conducted a literature search to identify effective nitrogen removal technologies that can be used as components of individual onsite sewage systems.

- The Washington Onsite Sewage Association (WOSSA) developed a training curriculum for onsite sewage professionals and conducted two training sessions in the Hood Canal region.

- The Washington Sea Grant program initiated a citizen involvement program designed to encourage homeowners to reduce nitrogen inputs to their sewage systems by removing in-sink garbage grinders and substituting microstrainers.

- Washington State University Extension agents are recruiting shoreline residents to become Hood Canal Stewards by adopting home site management practices that will reduce nitrogen inputs from onsite sewage systems and other potential sources around their homes.

- Three private sector contractors are installing three different types of onsite sewage treatment equipment with nitrogen removal capability; one contract involves development of a cluster system and a formal joint management agreement to be entered into by the owners.

- The Jefferson County Public Health agency will conduct monitoring of selected types of existing onsite sewage systems to assess their nitrogen reduction capabilities and monitor the abovementioned demonstration units to assess their performance.

- The Mason County Utilities Department and their consulting engineer are assessing a range of options for managing existing and future sewage treatment

needs in the area between Hoodsport and the Skokomish tribal lands located in the southern part of the Hood Canal watershed.

- The Kitsap County Health District staff carried out surveys of existing onsite sewage systems located along a portion of the easterly Hood Canal shoreline, sampled tributary drainages, and studied the relationship between fecal coliform concentrations and the concentration of nitrates in surface waters.

State and federal funding is supporting additional actions by HCDOP partners that are aimed at reducing nitrogen inputs to the Canal from onsite sewage systems. The Hood Canal Coordinating Council, the regional council of governments for Hood Canal, developed a survey instrument and conducted a survey of shoreline residents to assess attitudes about sewage management and determine whether economic incentives can be used to encourage homeowners to adopt better management practices. Mason County Commissioners and the Commissioners of Mason County Public Utility District (PUD) #1 adopted a joint resolution committing their respective governments to managing sewage through partnership efforts. The 2005 Washington Legislature committed $21.1 million to a variety of state and local projects that will reduce nitrogen inputs to Hood Canal. Of that total, $19,790,000 will be used to evaluate, design, construct, and test onsite, decentralized, and community sewage treatment facilities (Dohrmann, 2005).

QUESTIONS AND DISCUSSION

Efforts to solve low dissolved oxygen conditions in Hood Canal's marine waters are at an early stage. Much scientific work remains to be done by the Integrated Assessment and Modeling study group to develop the data that will populate and validate the Hood Canal water quality model. In the interim, the Corrective Action and Education group is committed to pursuing cost effective actions that will reduce nitrogen loadings while causing no harm. Achieving this objective poses a number of questions:

- What is the real cumulative nitrogen loading to Hood Canal that results from the use of existing onsite sewage systems in the watershed and is it significant in the context of other sources?

- What combination of centralized and decentralized sewage treatment facilities will best accommodate the present and future needs of the region?

- Will new sewage treatment technologies perform effectively under the conditions present in the watershed?

- If the application of nitrogen removal technology to onsite systems is needed to solve Hood Canal's low dissolved oxygen condition, what approaches will be effective in accomplishing its incorporation into existing and new systems?

A substantial literature exists that documents typical per capita human production of nitrogenous wastes, the limited ability of simple onsite sewage treatment systems to remove nitrogen, and the contamination by these systems of other coastal waters. Despite this evidence, many local residents and some regulators question whether effluent from onsite sewage systems in the watershed contributes significantly to the Canal's low dissolved oxygen condition. Providing an affirmative, supportable response to this question is crucial to implementing any action aimed at improving sewage treatment in the watershed. The work by Jefferson County Public Health described above seeks to increase the precision with which the potential contribution of existing systems can be estimated. Educational work by WSU Extension, Washington Sea Grant, and others aims to help watershed residents evaluate the relative importance of this nitrogen source.

While the preponderance of existing systems are residential sized onsite devices, the geographic scope of the low dissolved oxygen condition necessitates consideration of a range of sewage management options. Portions of two communities, Belfair and Hoodsport, exhibit sufficient development density to justify construction of collection facilities and treatment on a community scale. However, extensive stretches of shoreline are characterized by strip development adjacent to a parallel perimeter highway, interspersed with a number of small multi-parceled, residential subdivisions. In these latter areas, cluster treatment facilities could serve the combined sewage from small numbers of homes. The community faces pressure to allow new building and redevelopment of old, existing structures into larger residences. How to provide appropriate sewage management for these changes that occur primarily on a parcel-by-parcel basis poses a large challenge to the commissioners of Mason County and PUD #1.

Two prime considerations influence the potential effectiveness of onsite sewage systems that provide the advanced treatment needed to remove nitrogen. The naturally low alkalinity (~80 mg/l) of the area's fresh groundwater may limit the capability of any device that depends upon natural biochemical processes to nitrify raw sewage (Hull, 2005). The characteristic requirement for regular monitoring and maintenance of technologically more complex treatment devices combined with the lack of a responsible management entity in the watershed raises the concern that installation of such devices would be followed shortly by the occurrence of large numbers of system failures.

On-going management of onsite sewage systems now in use in the watershed is almost entirely dependent upon the voluntary commitment of their owners to employ private maintenance contractors to provide periodic pumping and repairs. The effectiveness of this approach has not been systematically assessed. The Mason County Department of Health Services requires that owners of complex systems obtain periodic maintenance inspections and report results to the agency. Department staff is currently engaged in shoreline surveys that will produce data on system performance. One small residential community of 18 homes, the Madrona Beach neighborhood, is served by a cluster system under active management by Mason County PUD # 1.

Since more-complex onsite systems are assumed to require more regular attention, it can be concluded that a robust management system will be useful and probably essential for

their long-term performance. Should the management system be a single entity? Have watershed-wide jurisdiction? Should it be a public or private utility, or a joint public/private venture? Should it take ownership of systems or require access easements on private property? Should it, or the local environmental health agency, require installation of nitrogen removal equipment on all new sewage systems? Should it require upgrades on all existing systems? How can homeowners be assisted in financing the cost of sewage system upgrades? These are a few of many questions being posed by residents, local officials, state legislators, and others as they grapple with the need to develop a more-effective management system.

CONCLUSIONS

The Hood Canal has exhibited the symptoms of hypoxia and monitoring data confirms that low dissolved oxygen conditions persist for extended periods. A broad partnership has developed to better define the causes of this condition and undertake remedial action.

Estimates of nitrogen inputs from onsite sewage systems, while coarse, do suggest that these systems are significant contributors of nutrients that promote the occurrence of algal blooms and ensuing oxygen consumption. Much attention and significant resources have been focused on finding ways to reduce the input of nitrogen emanating from onsite sewage systems. Achieving the necessary reduction will require that both technical and management obstacles be overcome.

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